Copper and Cashmere: a winning combination for the textile sector?

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Technical Textiles Based on Regenerated Wool: Process and Test of a New Generation of Fabrics

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ABSTRACT

The present study presents the main results of the Italian project Technical Wool, that was granted a subvention by the HI-TEX pilot Program 2007/2008 managed by Tuscany regional authority (Regione Toscana). The Technical Wool Project objective was to devise an innovative process able to confer to regenerated wool excellent properties in terms of dimensional stability, flammability and water repellence. The new process allows the creation of wool-based natural technical clothes. This new generation of fabrics may be considered considerably different from the conventional technical textiles, usually produced by means of artificial fibers. Moreover, while technical clothes are, generally, not fashion oriented, the secondary aim of the project was to confer to the new kind of textiles some aesthetic properties. The study describes both the innovative process for producing some experimental fabrics and the tests performed for measuring some technical properties such as flammability, water repellence and dimensional stability. The results of the tests carried out on these, experimental, fabrics show that the devised process is suitable for producing technical clothes using regenerated wool as basis raw material. The Project involved four SMEs (Toscolaniera S.p.A. Filatura Safic S.r.l., New Mill S.p.A. a private research centre and Tessitura TAM S.r.l.) located on the Prato province, a well known Italian textiles and apparel district that is undergoing a deep economic and industrial crisis.

Key words: Technical clothes, water repellence, flammability, dimensional stability

INTRODUCTION

Technical textiles account for nearly 70% of textile industries' product in developed countries like the US, Japan and Europe. Global demand for technical textiles will reach 85 billion dollars in a few years (Tewari, 2006). These encouraging data are attributable to a growing attention of the customer to textile materials of new generation that are characterized by high performances and that can be used not only when operating in technical operations but also in everyday use. Thus, a key challenge for worldwide textiles and clothing industry to remain competitive is to produce added value products and develop new manufacturing technologies to meet increasingly demanding customer requirements. Given that innovation in new materials, processes and products is an inherent feature of this sub-sector, expenditure on R and D is higher in this field than for conventional textiles (Holme, 2007). In the development of fibers, yarns and fabrics, functional aspects - such as thermal, or water proof functions-are playing an increasingly important role. Since, technical textiles are generally not fashion oriented, performance requirements and technical specifications determine the success of a product. Technical textiles can be divided into many categories, depending on their end use. The classification developed by Techtextil, Messe Frankfurt

Exhibition GmbH is widely used in Europe, North America and Asia (Liu *et al.*, 2006) and defines with the term Clothech (Clothing Textiles) the technical textiles for clothing applications (Sung, 2009). Clothech consume all kinds of fibers, i.e. natural fibers to high performance manmade fibers. However, the manmade and inorganic fibers comprise of 79% of total fibre consumption in technical textile applications as compared to 21% for natural fibers (Aizenshtein and Efremov, 2006). A large number of studies have been carried out in the last decades in the technical textiles field. An assessment of US comparative advantage in technical textiles was developed by Chi *et al.* (2005). The state of the art and the future challenges of the smart textiles is provided in a study performed by Lymberis and Paradiso (2008). Some comparative analysis of new materials used for advanced technical woven fabrics, has been made by Ivana *et al.* (2008). The use of regenerated or recycled fibers for realizing technical clothes is deeply described in a work developed by Bartl *et al.* (2005). According to the literature there is a need of using regenerated wool in order to obtain natural technical clothes. The present work describes the manufacture of technical fabrics characterized by a greater percentage of natural fibers. Accordingly, in this context, during 2007/2008 the Technical Wool Project experimented and tested a new process able to confer upgrading performances to wool-based textiles, with particular attention to both some technical properties and to aesthetic one. The Project was granted by HI TEX pilot Programme of the Regione Toscana which aim is to promote and foster the textile sector, focusing on quality and new approaches and to encourage the growth of an entrepreneurial approach including research allowing interchange of knowledge between companies. The Project involved four SMEs (Toscolaniera S.p.A. Filatura Safic S.r.l., New Mill S.p.A. a private research centre and Tessitura TAM S.r.l.) located on the Prato province, a well known Italian textiles and apparel district that is undergoing a deep economic and industrial crisis (Ottati, 2009).

The main objective of the present work was to process and create a new generation of textile with an high percentage of regenerated wool and described by some technical properties. More in detail, this new generation of textiles has to be typify by the following characteristics:

- **Good dimensional stability:** Shrinkage and shortening have to be comprised into 3%
- **Water proof:** The fabrics have to be classified into class ISO 3 or higher according to the international standard EN 24920:1993
- **Fire proof:** The fabrics have to be classified in Class 1 according to the standard C.F.R. PART 1610
- **Good aesthetic properties**

A fabric that satisfy the requirements may be considered a valuable Clotech. Moreover, the use of a large quantity of natural fibers confers some aesthetic and comfortable properties to the fabrics such as a better hand and softness.

MATERIALS AND METHODS

In order to obtain a new generation of Clothech the partners of the HI-TEX project developed the following tasks during 2007-2008:

- Selection and production of wool-based yarns
- Weaving of the produced yarns
- Finishing of the weaved fabrics
- Test of the finished new generation of fabrics

Selection and production of wool-based yarns: The first step of the project was to select and to produce a series of regenerated wool-based yarns characterized by several technical properties. More in detail two kind of yarns have been developed:

- Yarn composed by a mixture of regenerated wool and nylon
- Yarn composed by regenerated wool, nylon, viscose and cashmere

In the first case, some experimental tests performed by the New Mill laboratory, showed that the best compromise between the technical properties of the yarns and the capability of being spun can be reached with a wool fibre fineness comprised into the range (19.5-23 μm), with an optimal value equal to 22 μm. The use of a percentage of polyamide is required in order to increase the yarn tenacity (Carvelli *et al*., 2008). In the second kind of yarn developed by the technicians, the wool fibre fineness was set to 20.5 μm and the cashmere fibre fineness was set to 16.5 μm. Moreover, a percentage of polyamide and viscose have been added to the mix in order to improve the yarn performances. In Table 1 the composition, tex, yarn strength, maximum elongation and fibre fineness of the two kinds of yarns produced for the HI-TEX project are shown. In both cases the fibers have been prepared by means of a standard process (bale opener, willowing machine, carding willow and blow room) but with a modified lubrication (7% oil, 2% antistatic agent, 6% water). The two kind of yarns described above have been selected among a larger set of experimental yarns tested by the New Mill Laboratory. It is evident that the results, in terms of yarn strength and fibre fineness are excellent with regard to regenerated wool sector.

Weaving of the produced yarns: The two kind of yarn produced with the composition described in Table 1 have been used for producing a set of 7 weaved textiles. In Table 2, some properties of the 7 weaved textiles are shown. The textiles were weaved with different types of structure and in particular: Batavia, Plain Dobby and Dobby with several shafts.

Table 1: Composition, tex, yarn strength, maximum elongation and fibre fineness of the two kinds of yarns produced for the HI-TEX project

Yarn name	Composition	Tex (g km^{-1})	Yarn Strength (cN)	Maximum elongation (%)	Fibre fineness (μm)
X171C	Wool: 80% Polyamide: 20%	67	250	14	22
X931C	Wool: 35% Cashmere: 20% Viscose: 30% Polyamide: 15%	71.4	280	8	20.5

Table 2: Structure, height and weight properties of the 7 weaved textiles obtained, respectively, with yarns X171C (first three) and X931C (remaining four)

Fabrics	Structure	Yarn used	Height (mm)	Weight (kg m^{-2})
R	Batavia	X171C	2.065	167.00
S	Batavia	X171C	2.200	165.00
T	Batavia	X171C	2.000	159.00
Rif. K	Dobby 8 Shafts	X931C	2.230	163.00
Rif. X	Plane Dobby 4 Shafts	X931C	2.215	160.00
Rif. Y	Dobby 8 Shafts	X931C	2.375	154.00
Rif. Z	Dobby 16 Shafts	X931C	2.530	158.00

Table 3: Loom efficiency and speed for weaving the 7 prototypes. The loom inactivity, the number of warp yarns and the density are also listed

Fabrics	Loom efficiency (%)	Loom speed	Loom inactivity (min h^{-1})	No. of warp yarns	Density
R	94	400	3 ½	2560	7.42
S	95	450	3	2560	7.05
T	97	450	2	2300	7.23
Rif. K	94	400	3 ½	5244	14.43
Rif. X	92	450	4 ½	2300	6.49
Rif. Y	94	450	3 ½	3416	9.34
Rif. Z	97	400	2	3000	7.50

A Vamatex Weaving Loom (Seyam, 2000) was used for weaving the textiles. The high resistance of the yarn allowed to setup a high number of strokes per minute, equal to 400-450. As wide known and further demonstrated by Lord and Mohamed (1992) in order to reach an optimal weaving speed, yarn friction and fibre shedding must be decreased while yarn smoothness must be increased. The yarn smoothness may be described in terms of weaving loom efficiency: a good smoothness is reached when the loom is characterized by high efficiency (>90%) when working with high strokes per minute. In Table 3 the loom efficiency for weaving the 7 prototypes is showed. The number of minutes per hour in which the loom remains inactive is also indicated. Since, the object of the project was to realize technical textiles, another important parameter that has to be considered by the technicians is the textile density, expressed as the ratio between the number of warp yarn and the total weight of the fabric. When this ratio is equal or greater than 6.5, the fabric may be considered as a compact one. Table 3 shows that the selected yarns have a good smoothness; moreover in the Table 3 the textile density of the 7 prototypes is also showed.

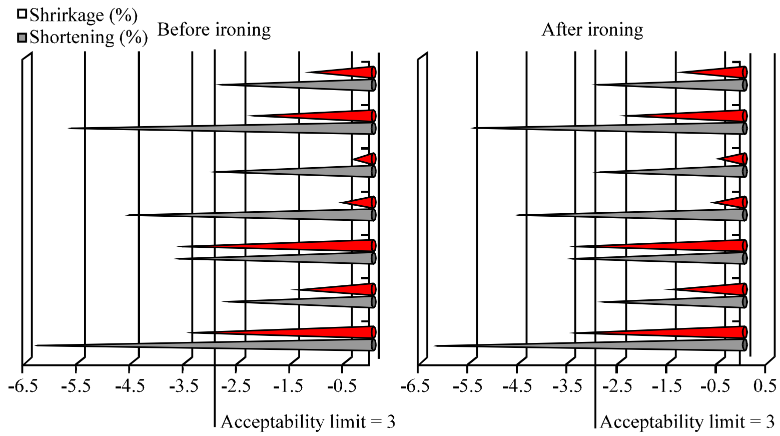
Finishing of the weaved textiles: Once weaved, the fabrics have to be finished in order to confer some technical properties such as fireproof, waterproof and shrink proof.

The finishing phases adopted by the technicians, wide known in the state of the art, are the followings (Vinzanekar *et al.*, 1996):

- **Washing and drying with tenter frame:** The fabric is held firmly at the edges by pins or clips on the two chains that diverge as they advance through the heated chamber, adjusting the fabric to the desired width
- **Decatizing:** The fabric, wound tightly on a perforated roller, has steam blown through it. The process is aimed chiefly at improving the hand and removing wrinkles
- **Textile chlorination:** The fabrics are treated with chloral, hypochlorite and dichloroisocyanuric acid with 3-4% on mass of fibre (omf), at pH 10 and a temperature of 20-40°C. This treatment, that lasts 1 h, allows the improvement of the dyeing affinity
- **Polytetrafluoroethylene coating (Da-Yeon *et al.*, 2009):** The fabrics are coated with Teflon in order to confer both waterproof characteristics and an increased resistance to the effect of high temperatures and corrosive chemicals. Moreover, the Teflon treated fabrics shows a low frictional coefficient and a slippery hand. The coating has been applied to the fabrics with an amount of 60 g L^{-1} of Teflon

RESULTS

The 7 fabrics used as a test set of the whole set of produced and finished textiles have been tested in order to assess their technical properties. Specifically, three kind of test have been



	Before ironing		After ironing	
	Shortening %	Shrunkage %	Shortening %	Shrunkage %
R	-6.4	-3.5	-6.3	-3.5
S	-2.8	-1.4	-2.9	-1.5
T	-3.7	-3.7	-3.6	-3.5
Rif. K	-4.7	-0.6	-4.6	-0.7
Rif. X	-3.0	-0.4	-3.0	-0.6
Rif. Y	-5.7	-2.3	-5.5	-2.4
Rif. Z	-2.9	-1.2	-3.0	-1.3

Fig. 1: Results of relaxation shrinkage of warp and weft before and after ironing for the 7 fabrics obtained with the 2 kinds of new yarns

performed on the fabrics: 1) dimensional stability after subsequent washing and drying cycles, 2) water repellent capabilities and 3) flammability.

Dimensional stability was assessed according to international standard EN ISO 6330:2002 using an horizontal rotating washing machine. The washing temperature was maintained to 40°C. The ironing is performed at the temperature of 110°C. The dry mass of each specimen is 2±0.1 kg and a cotton ballast was used during washing. As described in the normative, the dimensional stability is expressed in terms of shortening and shrinkage; the two parameters were measured before and after ironing. Results of relaxation shrinkage of warp and weft are shown in Fig. 1. As wide known shrinkage and shortening values less than 3% may be considered valuable for technical textiles (Savile, 1999).

The water repellent capabilities have been assessed by measuring the resistance to surface wetting by means of a spray test. The test was performed according to the international standard EN 24920:1993. As widely known (Minazio, 1995) this standard defines 5 indexes (ISO 1, ISO 2, ..., ISO 5) each one corresponding to a specific value of the AATCC (American Association of Textile Chemists and Colourists) photographic scale (Weaver, 1984). The higher is the value of the ISO index and the higher is the water repellence, as depicted in Fig. 2a-e. A fabric is characterized by a good water repellence if its ISO index, measured according to the normative, is greater than 4. The fabrics have been set in environment at temperature 20±2°C and with a 65±1% RH moisture. The results of the water repellence test, performed to the 7 test fabrics in three replications, are showed in Table 4. The fireproof of the 7 test fabrics was assessed according to the standard C.F.R. PART 1610 (Wu and Yang, 2008) that provides methods of testing the flammability of clothing and textiles intended to be used for clothing establishes three classes of flammability, sets forth the requirements which textiles shall meet to be so classified and warns against the use of those textiles which have burning characteristics unsuitable for clothing. More in detail the normative provides the following three classes:

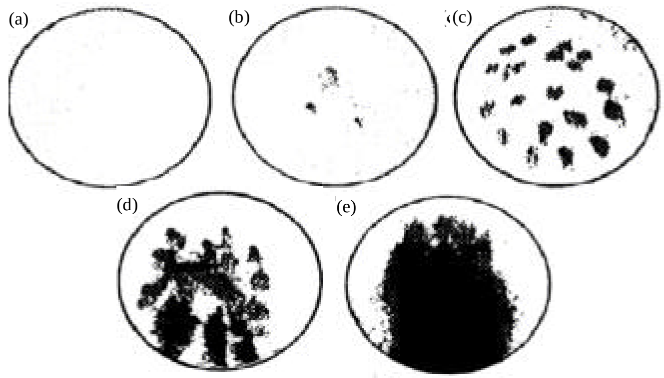


Fig. 2: Visual description of the 5 ISO indexes (ISO 1, ISO 2,..., ISO 5) for assessing the spray test. The higher is the value of the ISO index and the higher is the water repellence (a) ISO 5 (100), (b) ISO 4 (90), (c) ISO 3 (80), (d) ISO 2 (70) and (e) ISO 1 (50)

Table 4: Results of the water repellence test, performed to the 7 test fabrics in three replications and under different temperature

Fabrics	Water temperature	ISO index (I replication)	ISO index (II replication)	ISO index (III replication)
R	20.2°	4	4	4
S	20.3°	4	4	4
T	19.5°	4	4	4
Rif. K	20.5	3	3	3
Rif. X	18.5	4	4	4
Rif. Y	18.5	5	5	5
Rif. Z	19.3	4	4	4

- **Class 1 (Normal flammability):** This class includes textiles without nap, pile, tufting, flock, or other type of raised-fiber surface, when the time of flame spread is 4 sec or more. Also a textile napped, pile, tufted, flocked, or other having a raised-fiber surface is defined in class 1 when the time of flame spread is more than 7 sec, or when they burn with a rapid surface flash (from 0 to 7 sec), provided the intensity of the flame is so low as not to ignite or fuse the base fabric
- **Class 2 (Intermediate flammability):** This class includes textiles napped, pile, tufted, flocked, or other textiles having a raised-fiber surface with a time of flame spread from 4 to 7 sec, both inclusive and the base fabric ignites or fuses
- **Class 3 (Rapid and intense burning):** This class includes textiles dangerously flammable and recognized by the trade as being unsuitable for clothing because of their rapid and intense burning. In case of textiles free from nap, pile, tufting, flock, or other type of raised-fiber surface the time of flame spread is less than 4 sec. In case of napped, pile, tufted, flocked, or other textiles having a raised-fiber surface the time of flame spread is less than 4 sec and the intensity of flame is such as to ignite or fuse the base fabric

The fabrics are tested in two different conditions: as received and after refurbishing. For each of the 7 test fabrics a number of 5 specimens is tested according to the normative (the time of flame spread of the textile is taken as an average time for 5 specimens). The refurbishing process comprises a washing (at 50°C) a dry cleaning at 66°C and a cooling at environment temperature. The flammability tester consists of a draft-proof ventilated chamber enclosing a standardized ignition medium, sample rack and automatic timing device. The test shows that all the fabrics have been classified into Class 1 before and after refurbishing.

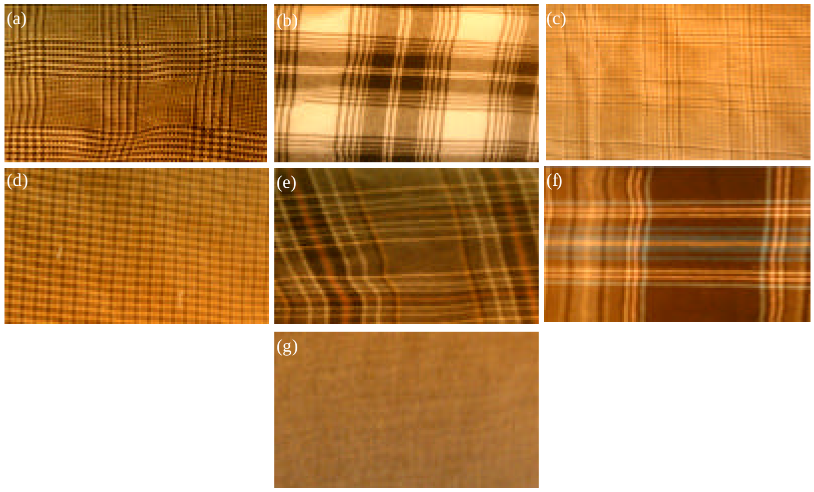


Fig. 3: A picture of 7 specimens of fabrics obtained with the new method. (a) R, (b) S , (c) T, (d) RIF X, (e) RIF X, (f) RIF Y and (g) RIF Z

DISCUSSION

The results of the test performed for the 7 test fabrics may be summarized as follows. Figure 1, it may be noticed that fabrics identified by the code S, Rif. X and Rif. Z are the only one respecting the shrinkage and shortening values required by the Clotech definition (Seyam, 2000). In other words, among the 7 kind of fabrics developed during the project, only three of them respects the definition of technical textiles. Anyway this result may be considered a good advance in the field because of the use, as already stated, of regenerated wool as a substitute of artificial fibers. Moreover, with regard to the water repellent characteristics, these three innovative and experimental fabrics have been classified into class ISO 4. Finally, all the fabrics have been classified into Class 1 in terms of flammability. According to these results the fabrics S, Rif. X and Rif. Z may be classified as Clotech. Furthermore, all the devised fabrics have shown a good water repellence. This is an important task because the objective of the work was to obtain a technical textile with good water repellence but not to obtain a totally waterproof cloth (Yáñez *et al*., 2006). Reassuming, the tested fabrics shows good aesthetic properties being based on the use of regenerated wool instead of inorganic fibers. In Fig. 3a-g a specimen of each of the 7 test fabrics is showed. The aesthetic properties of these fabrics have been evaluated by the companies customers.

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